

1912  
G33

GEST

Cost Analysis of  
a Reinforced Concrete Warehouse

Architectural Engineering

B. S.

1912



UNIVERSITY OF ILLINOIS  
LIBRARY

Class

1912

Book

633

Volume









**COST ANALYSIS OF  
A REINFORCED CONCRETE WAREHOUSE**

**BY**

**BEN GEST**

-----  
**T H E S I S**

**FOR THE**

**DEGREE OF BACHELOR OF SCIENCE**

**IN**

**ARCHITECTURAL ENGINEERING**

-----  
**COLLEGE OF ENGINEERING**

**UNIVERSITY OF ILLINOIS**

**1912**

1912  
G33

1912.

638

UNIVERSITY OF ILLINOIS

May 29 1912

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Ben Gest

ENTITLED COST ANALYSIS OF

A REINFORCED CONCRETE WAREHOUSE

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in

Architectural Engineering.

James M. White

Instructor in Charge

APPROVED:

Frederick W. Mann

HEAD OF DEPARTMENT OF Architecture.

226381





# T A B L E O F C O N T E N T S .

## Part I.


### General Description.

	Page.
Building and Grounds, - - - - -	1-3.
Line Drawing showing Building and Grounds, - - - - -	3
Elevation of a Tier of Columns, - - - - -	15.
Forms, - - - - -	4
Reinforcement, - - - - -	5
Concrete, - - - - -	5-8.
Materials, - - - - -	5-7.
Mixing, - - - - -	7.
Depositing, - - - - -	7.

## Part II.

### Cost Data.

Cost of Forms - - - - -	10.
Cost of Reinforcement, - - - - -	11.
Cost of Concrete, - - - - -	13.
Total Cost of Reinforced Concrete, - - - - -	14.



Digitized by the Internet Archive  
in 2013

<http://archive.org/details/costanalysisofre00gest>

## COST ANALYSIS OF A REINFORCED CONCRETE WAREHOUSE.

### Part I.

#### General Description.

##### Building and Grounds.

The warehouse, in the construction of which the data herewith was obtained, was erected by a farm-implement manufacturing company in northern Illinois. The writer was employed upon this building in different capacities, part of the time in the drafting room, part of the time as timekeeper, and the remainder as foreman in charge of the gang of laborers. It is by the courtesy of the architect in charge of this building that this data was obtained.

The warehouse is an eight-story structure, 115 ft. wide and 235 ft. long. It is of the "flat slab" type of construction. The exterior walls, which are of brick, are not self-supporting, but are carried on lintels of reinforced concrete. These lintels and the concrete piers into which they frame are visible on the outside of the building, thus dividing the wall surface into panels. The entire structure, with the exception of the brick curtain-walls referred to above, is of reinforced concrete.

All interior columns are circular and range from 2 ft. 8 in. in diameter at the basement to 18 inches at the top story. Wall columns are rectangular in section and are of uniform width throughout the height of the building, the thickness varying. At one end of the building the wall columns are of the same section





as the interior columns, as they will become interior columns when the proposed extension of the building in that direction is erected.

All floor slabs are ten inches in thickness, with the exception of the seventh and eighth floors, which are 8 1/2 in. thick. The first floor was calculated for a live load of 300 lb. per sq. ft. and the remaining floors for a live load of 250 lb. per sq. ft.

The outside floor panels are 17'-6" x 20'-0" except the corner ones which are 17'-6" x 17'-6". The inside panels are 20'-0" x 20'-0".

The roof is a reinforced concrete slab seven inches in thickness. It is pitched from the center-line toward either edge and also from the ends of the building toward the middle.

On the north side of the building is the loading track. The brick curtain-walls are left out on the first floor on this side of the building and the entire space filled with rolling shutters, so that implements may be loaded from the first floor directly into the cars. The first-floor level is 4'-0" above grade for convenience in shipping.

Attached herewith is a line-drawing showing the general location of the warehouse with reference to the other buildings. The position of the mixers and hoists are also shown in this diagram. It should be noted that the storage ground for the materials used in the construction of the building is very limited and the consequent inconvenience caused thereby was quite appreciable. About the only storage-ground available was a little on the north side of the building and on the east. The south side of the





BUILDING

BUILDING

TRACKS

CEMENT

SAND  
ROCK.

WAREHOUSE 235' x 115'

BUILDING

STEEL STORAGE  
HERE.

BUILDING.

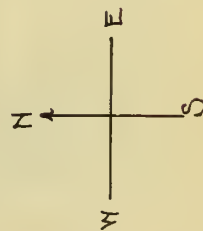
HOIST

MIXER

MIXER

HOISTING ENGINE

NOTE: THIS SPACE NOT AVAILABLE  
FOR STORING MATERIALS.  
TEMPORARY WHEEL STORAGE  
HERE.



PLAN OF GROUNDS.

SCALE: 1" = 60'-0"



building was not available for storage, because the factory used this space for the temporary storage of wheels.

#### Forms.

In selecting lumber for the forms, sizes and lengths were used that would give the greatest probable salvage at the completion of the building. 4 x 4's were used for vertical supports, as it was found after experimenting with 2 x 4's doubled that 4 x 4's were stiffer and could be split into 2 x 4's on the rip-saw at a less expense than the cost of doubling the 2 x 4's and taking them apart and drawing the nails after they had served their purpose as supports for the forms. Upon these vertical supports rested 4 x 10 girders made up by spiking together two 2 x 10's. These girders were spaced 6'-8" on centers. Upon these girders and at right-angles to them were placed 2 x 8 floor joists, 2'-0" on centers. The flooring boards were built up into panels 2'-6" wide and 8, 14, and 16 ft. long by means of 7/8" battens secured by six-penny common wire nails. The use of panels facilitated the handling and placing of the floor, and as each panel could usually be held in position by one six-penny common nail at each corner, the removal of the forms was made much easier than it would have been had each board been nailed separately to the joists. It was also found that the damage to the floor as well as to the joists was reduced by this method to a minimum.

The lumber in the forms was used three times and at the completion of the work there was a salvage of about two-thirds of the original material.

The principal loss in the form lumber was occasioned by the fitting around the circular column heads, as it was found





to be practically impossible to place the forms so that they would fit together in the same position with reference to the columns heads in their second application as in the first.

The forms for the interior columns were of sheet metal, so constructed as to be used indefinitely by adjusting the form to the diameter required. Iron clamps kept the forms from spreading.

#### Reinforcement.

Slab reinforcement for each panel consisted of 7/16" round rods placed in four bands, as illustrated in the accompanying photographs.

The lintel reinforcement was Kahn bars supplemented by rods and stirrups.

The column reinforcement was 1" and 1 1/8" round rods placed inside of a spiral. The lower columns had double spirals.

#### Concrete.

##### (a) Materials:

The crushed stone used in the concrete was a local limestone free from fireclay and of very good quality, crushed to pass through an inch ring, with the dust and small stone screened out. The crushed stone was brought to the building in bottom-dump cars, the purpose being to dump the stone onto the space between the car and building, so that it would be readily shoveled into the basement, which was the only available storage space for crushed rock. It was found, however, that the bottom-dump cars did not work very successfully because of the large quantity of rock which would fall between the ends of the gates onto the space beneath the car, thus making it necessary for the shovelers





to get under the car and shovel this portion of the rock into the basement. Several side-dump cars were used at a very great saving of labor in unloading the crushed stone, but as it was impossible for the railroad company to furnish this type of car, this saving could not be made. Sometimes there would be a shortage of dump cars and the rock would come in ordinary coal cars, in which case it was necessary to shovel the rock over the side of the car onto chutes in the space between the car and the building, from which it would run into the basement. The height of the basement being only about ten feet, it was found necessary to shovel the crushed stone back from the windows to prevent choking up the chutes. This increased the cost of unloading the crushed stone, which will be seen, by referring to the cost data given below, to be the largest factor in the cost of the concrete.

The sand used was good, sharp, clean river sand which was loaded directly from the barge in the river into cars and brought to the building. The manner of unloading the sand was similar to that described for the crushed stone, but on account of the difference in the character of the material it was unloaded much more economically. The use of the bottom-dump cars, for the same reason as suggested above in connection with the stone, was abandoned and the sand thrown over the side onto aprons which would chute it into the basement. As the sand constitutes a smaller proportion of the bulk of the concrete than the rock, it was stored in parts of the basement more distant from the mixers than the rock. This arrangement was, however, difficult to maintain because of the impossibility of getting stone and sand delivered at the building in the proper proportions.



The cement was stored in a cement shed at the west end of the building and was taken into the basement, as needed, through a chute and wheeled to the mixer.

(b) Mixing:

The mixing plant was located in the basement at the bottom of the elevator well and consisted of two Smith mixers, one on either side of the hoisting tower, which extended up through the elevator shaft. One of the mixers had a dumping device by means of which one man, the engineer, could operate the machine. The other machine, however, was not equipped with this device, so that it was necessary to have an extra man on this machine to dump it. The mixer with the dumping device was, of course, used as much as possible. The mixers were charged from loading platforms with runways leading to the various material piles. Both machines were equipped with batch-loaders.

In order to avoid making smoke in the building, the engines on the mixers were connected up with live steam from the factory. The exhaust from the engines was used when necessary for heating water and sand.

(c) Depositing:

The Smith Concrete Elevator was used for hoisting the concrete. The tower, which was of timber, extended up through the elevator shaft. The tower was double, two hoisting buckets being used, one for each mixer. Cams were attached to the guides at the level of the mixer in order to throw the lip of the bucket to the front, so as to enable it to pass the nose of the mixer. The buckets were automatically dumped by means of a switch which could be set at any desired height.





Both buckets discharged into a central hopper which was moved from floor to floor as the building advanced.

Two-wheeled carts were used for transporting the concrete from the hopper. It was found that the concrete could be handled much more easily by the use of these carts than by wheelbarrows.

The runways for the carts were made of tables about eight feet long by three feet six inches wide and twelve inches high, made of two-inch plank. Good, solid runways were thus afforded which could be moved as desired, and as the legs were small at the bottom they passed readily through the reinforcement and made it possible to place the tables in any desired location.

During cold weather it was necessary to heat the materials for the concrete to prevent freezing. The sand was heated by pipe coils under the sand, through which exhaust steam from the engines was passed. The water was heated in a storage boiler near the mixers by means of a steam jet.

It was decided that it was not necessary to heat the rock, as it was dry when delivered at the job, and was kept in a good dry place and was free from ice.

The building itself was heated by salamanders in which charcoal was burned to avoid smoking up the building. The brick curtain-walls had not yet been put in, so a temporary enclosure was made of canvas. With these precautions it was found that the concrete remained practically at a constant temperature of about 46 degrees F. during the first 48 hours after being poured.



## Part II.

### Cost Data.

The cost data given herein is based upon the following rates of wages: common labor, 22 1/2¢ per hour; carpenters, iron workers, and engineers, 50¢ per hour.

Most of the laborers were foreigners, many of whom could not talk English. The work was carried on during the fall and winter up to Jan. 1st, so that some of it was done under unfavorable weather conditions, thus increasing the labor cost.

The cement cost \$1.25 a barrel, including freight; crushed stone cost \$1.31 1/3 per yard, including freight; sand cost 48¢ per yard, including freight. The average cost of lumber was \$22.90 per 1000 ft. The average cost of reinforcement was \$37.47 per ton, including freight.

### Cost of Forms.

Lumber was provided for forms for three stories, and as there were nine floors poured, including the roof, the lumber was used three times. Sixty-eight feet, B.M., of lumber were required per cubic yard of concrete, which at \$22.90 per 1000 ft. would amount to \$15.60. Since the forms were used three times, the final cost of the lumber is one-third of \$15.60, or \$5.20 per cubic yard of concrete.

Most of the lumber was used in and about the factory for remodeling work, making bins, and for various other purposes, so that to be fair the cost of the lumber should be divided by four instead of three. As this, however, would not be possible in all cases, it may be misleading to make a further reduction in the cost of the lumber.





It was found that the principal difficulty in using the panels more than three times was that they became very much roughened by use, so that the bottom of the slab did not present a smooth surface as in the case of the first use of the forms. This doubtless could be overcome by treating the forms with a wash of some sort to prevent the adhesion of the concrete.

The following tables give the unit costs of the different operations per cubic yard of the total concrete in the floor, including columns.

Cost of Labor on Forms.

	Per Cu. Yd. Concrete.
Making Panels and Wedges, - - - - -	-\$0.0454
Transporting and Hoisting, - - - - -	.1388
Distributing, - - - - -	.1388
Erecting:	
Columns, - - - - -	.1365
Lintels, - - - - -	.1365
Floor, - - - - -	.2730
Substructure, - - - - -	.4125
Bracing and Plumbing Columns, - - - - -	.0910
Leveling, - - - - -	.0590
Removing and Cleaning Forms and Bracing Floor, -	.0885
Repairing Forms, - - - - -	.1365
#Steel Column Forms, - - - - -	<u>.3300</u>
Total Labor on Forms, - - - - -	-\$1.9865
Cost of Lumber as given above, - - - - -	<u>-5.20</u>
Total Cost of Forms, - - - - -	\$7.19
#Includes rental of forms and all labor of putting up and taking down.	

The average cost of forms per sq. ft. of floor is about 20¢.



Cost of Reinforcement.

Cost of Labor on Steel.

Unloading, - - - - -	\$0.840 per 1000 lb.
Hauling and Hoisting:	
Unskilled Labor, - - - - -	.775 " " "
Skilled Labor, - - - - -	.409 " " "
Distributing, - - - - -	.551 " " "
Placing and Wiring, - - - - -	1.785 " " "
Column Erection, - - - - -	.760 " " "
Rod Bending, - - - - -	.107 " " "
Inspection, - - - - -	<u>.268</u> " " "
Total Labor Cost, - - - - -	\$5.495 per 1000 lb.

The total amount of steel per cubic yard of concrete is 188 lb.

Cost of Labor per cu. yd. of concrete, - - \$1.04

Cost of Steel per cu. yd. of concrete, - - 3.53

Total Cost of Reinforcement, - - - - - \$4.57 per cu.yd.con.





A portion of the shipment of the round rod reinforcement was made without tying the rods into bundles. This greatly increased the cost of unloading the steel, as the rods were very badly tangled. It also increased the cost of storing the same, as the different lengths had not been kept separate in the shipment.

The steel reinforcement for the basement and first-story columns extended from four feet below the basement floor up to two feet above the second floor and was ordered and shipped in one length. While this is good construction, it proved to be very expensive in the handling and erection of the steel.

These two items increased the total cost of labor, as will be seen by an inspection of the table of costs given above.



Cost of Concrete.

Cost of Labor on Concrete.

Per Cu. Yd.  
Concrete.

Unloading Materials, (rock, sand, cement) - - - - -	\$0.4594
Loading into Barrows and wheeling to Mixer, - - - - -	.3064
Mixing and Dumping into Hoisting Bucket, - - - - -	.1460
#Hoisting and Loading into Carts, - - - - -	.0873
Wheeling from Hoist to Place, - - - - -	.1230
Spreading, Puddling, and Changing Runs, - - - - -	.0689
Pointing up Columns and Ceilings, - - - - -	.0713
Building and Removing Screeds, - - - - -	.0318
Cleaning and Wetting down Forms, - - - - -	.0344
Inspection, - - - - -	<u>.075</u>
Total Labor Cost, - - - - -	\$1.4035
Cost of Materials, - - - - -	<u>3.40</u>
Total Cost of Concrete, - - - - -	\$4.80

#Including cost of labor on building hoist.

As noted in the general description, the labor cost could have been materially reduced by a different method of handling and storing the raw materials, as for example: By means of a pit below the track the stone and sand could have been unloaded without the extra shoveling, and the material could have been raised from this pit by some mechanical means to a bin above the mixer, into which the stone and sand would run by gravity.





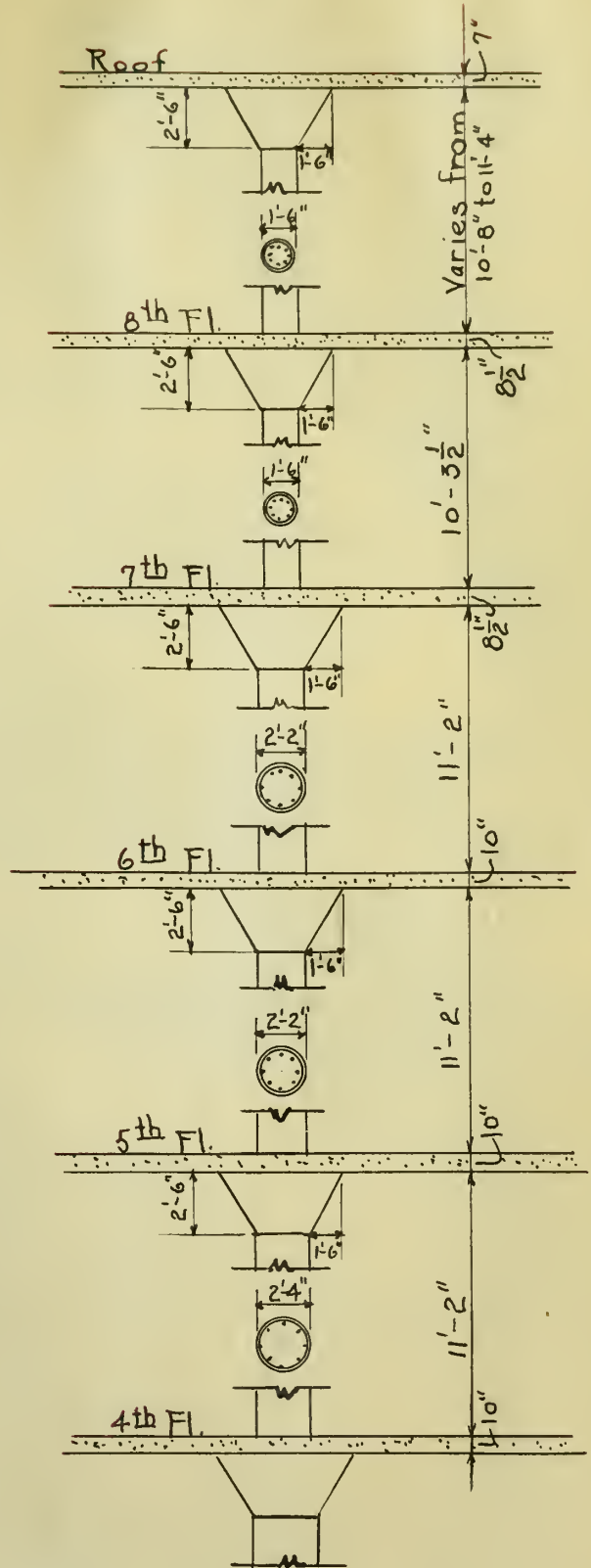
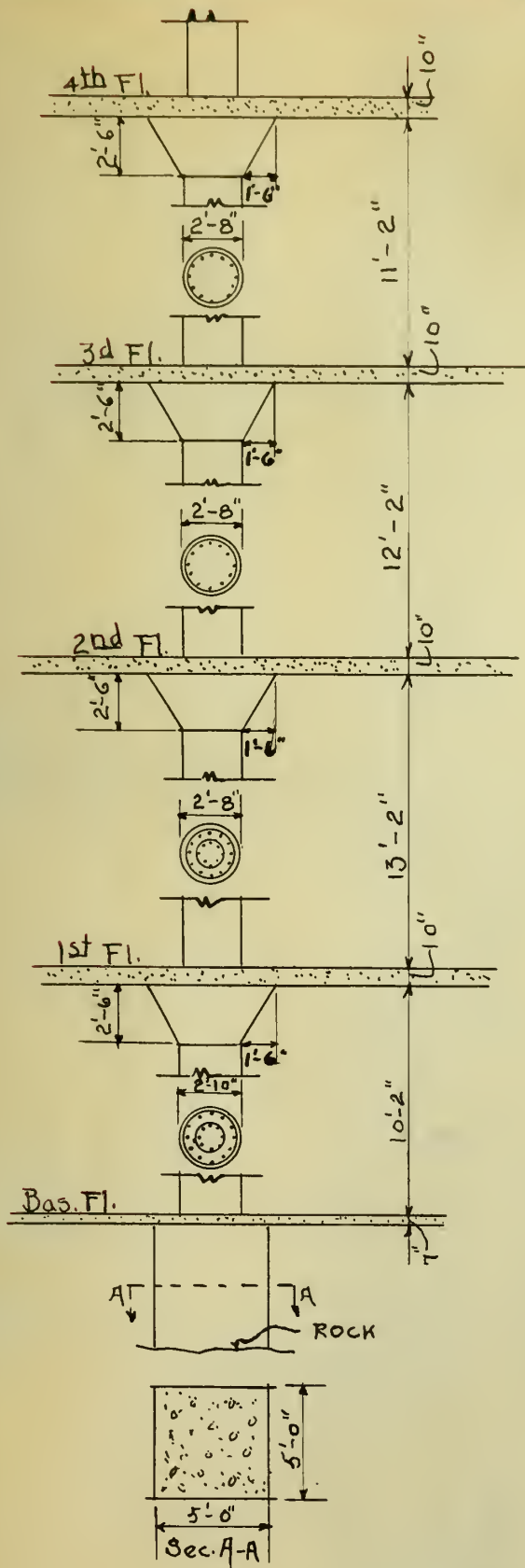
Total Cost of the Concrete in Place in the Building.

	Per Cu. Yd. Concrete.
Cost of Forms, - - - - -	\$7.19
Cost of Reinforcement, - - - - -	4.57
Cost of Concrete, - - - - -	<u>4.80</u>
Total Cost of Reinforced Concrete, - - -	\$16.56

The average cost of columns per cu. yd. of concrete in the columns is about \$22.70.

The average cost of the slab per cu. yd. of concrete in the slab is about \$15.00.





TIER OF COLUMNS.

SCALE:  $\frac{1}{8}" = 1'-0"$





061-6-10



LIBRARY  
OF THE  
UNIVERSITY OF ILLINOIS.

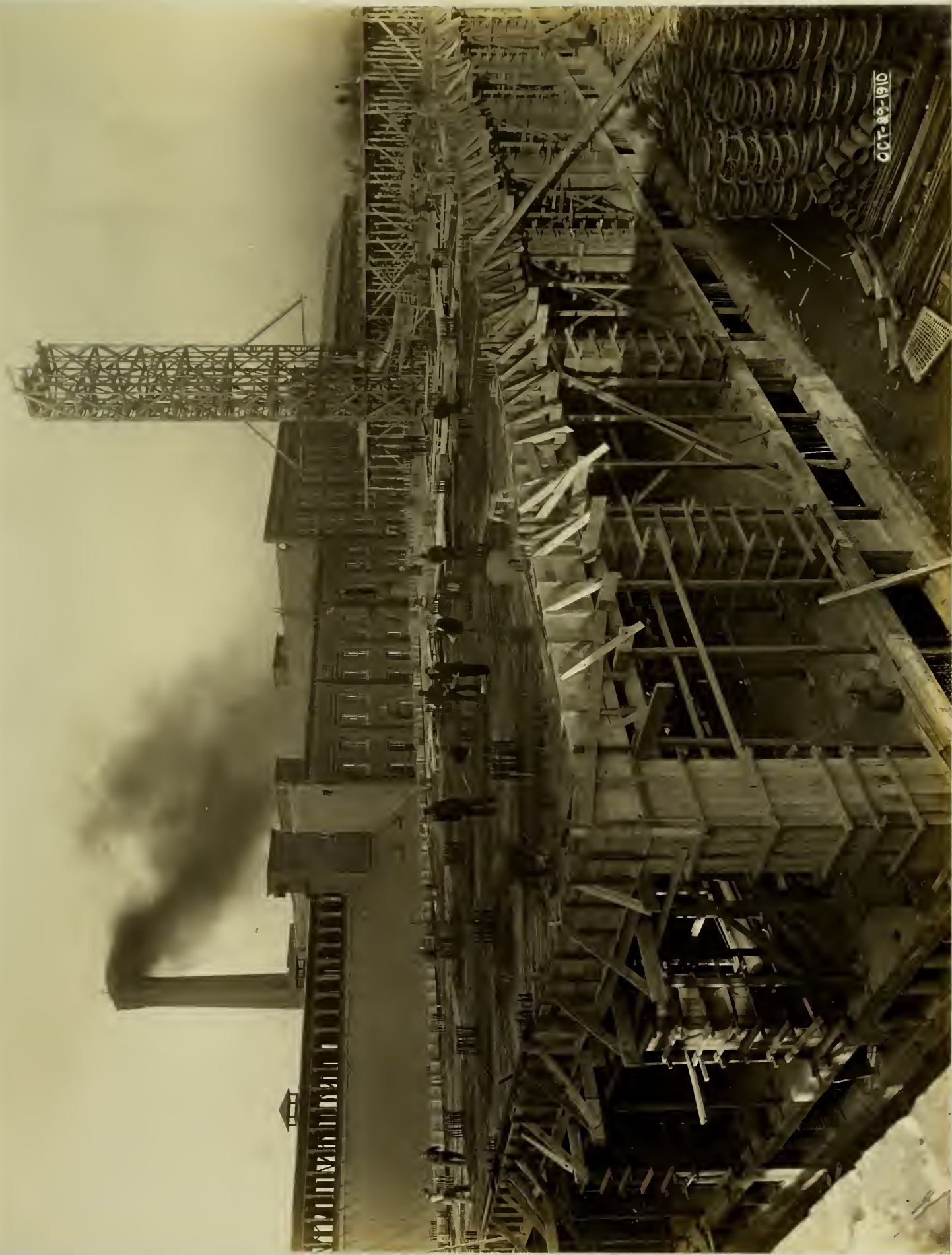
OCT-11-1910





LIBRARY  
OF THE  
UNIVERSITY OF ILLINOIS.

001-68-120





LIBRARY  
OF THE  
UNIVERSITY OF ILLINOIS



NOV-11-10

LIBRARY  
OF THE  
UNIVERSITY OF ILLINOIS





LIBRARY  
OF THE  
UNIVERSITY OF ILLINOIS





358

MAY-10-1911



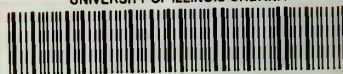








UNIVERSITY OF ILLINOIS-URBANA



3 0112 079094659